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The structure of deception: Validation of the lying profile questionnaire

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Abstract

The conceptualization of deception as a dispositional trait is under-represented in the literature. Despite scientific evidence supporting the existence of individual differences in lying, a validated measure of dispositional deception is still lacking. This study aims to explore the structure of dispositional deception by validating a 16-item questionnaire to characterize individuals' lying patterns. The final sample included 716 participants (Mean age = 25.02; 55.87% females) who were recruited via posters, flyers, and online social media platforms in Singapore. Our findings suggested four distinct latent dimensions: frequency, ability, negativity, and contextuality. We established the convergent validity of our measure by showing significant relationships with social desirability, malevolent traits, cognitive control deficits, normal and pathological personality traits, as well as demographic variables such as sex, age, and religiosity. Overall, the present study introduced a general framework to understanding deception as a dispositional trait.

Keywords Deception · Lying · Questionnaire · Psychopathy · Personality

The scientific study of deception and lying has had a turbulent history, nourishing key developments in ethics and philosophy, and sometimes being *(mis)*used for forensic or political purposes. Although often put at the forefront of public attention through a criminological or psychopathological lens, the topic remains at the crossroads of different fields even within psychology. For example, although deception is a common phenomenon, practiced by virtually all (Kashy & DePaulo, 1996), the emphasis has often been placed on lie detection or pathological cases. Thus, it seems that a general framework for understanding this phenomenon at the population level is still lacking.

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Using an integrative framework, we propose to conceptualize deception as the process of achieving an inaccurate experience of a piece of information in relation to its objective qualities. This definition is neutral to the nature of the object and its cause, i.e., not limited for instance to verbal information (visual illusions could be interpreted as a form of sensory deception), humans (deceptive behaviours being documented in other species; e.g., Hirata, 1986; de Waal, 2005) nor specific purposes (e.g., being necessarily beneficial for the deceiver, as suggested by Bond & Robinson, 1988). As such, the study of this form of reality bending could benefit from being placed within a larger framework of the sense of reality and its naturally connected neurocognitive functions such as perception, emotions or consciousness (Makowski, 2018; Makowski et al., 2017; Riva et al., 2007; Seth et al., 2012).

Lying is a form of intentional deception. It includes the creation and delivery of information that is believed to be inaccurate, with the aim of making it believed to be accurate (note that both deception and lying are used interchangeably in the context of this study). While lying is often studied as an act, involving but not limited to its production or reception, lying could also be understood and investigated as a dispositional trait, i.e., as a metastable characteristic of personality. In fact, one of the motivations supporting this perspective is the emergence of evidence supporting the existence of inter-individual variability in lying.

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Since lying can be described as a common and potentially universal phenomenon (Kashy & DePaulo, 1996), one naive hypothesis could be that individual differences are less relevant than situational factors (Aquino & Becker, 2005). However, empirical evidence has recently rebutted the assumption of ubiquitous lying behaviors, suggesting that the extent to which people engage in lying varies considerably from one individual to the next (Gozna et al., 2001; Kashy & DePaulo, 1996). For instance, differences have been observed between participants in the frequency of lying, their (perceived) ability to tell and detect lies, the emotions associated with lying (e.g., guilt) or the moral attitude toward it (Serota et al., 2010; Serota & Levine, 2015). Importantly, these patterns have been shown to be related to other interindividual variables (e.g., sex and age differences, with men and younger people lying more frequently; DePaulo et al., 1996; Jensen et al., 2004). In spite of this evidence, most experimental research on deception has overlooked trait-like interindividual variability, and has instead focused on the behavioral and neural correlates of lying and lie detection. Critically, it is possible that the absence of such control of trait-deception in experimental studies is related to a lack of validated questionnaires made to assess individual variations in lying.

However, using self-report questionnaires as a measure of deception inherently begs the question of whether results may be contaminated by response bias and distorted perceptions in self assessment. Although the issue of deception assessment using self-report tools being beyond the scope of this study, past studies have demonstrated some level of support for its suitability. Self-reported lying frequencies have been shown to converge with respondents' estimations of others' lying tendencies (Serota et al., 2010), as well as real life dishonesty in the lab (i.e., cheating on a task; Halevy et al., 2014). A methodologically rigorous approach is also crucial in eliminating any potential caveats. This includes accounting for social desirability to adjust for each subject's bias (Fisher & Katz, 2000; Serota et al., 2010) and encouraging accurate reporting through guaranteeing data anonymity (Serota & Levine, 2015) and providing a clear definition of lying in the questionnaire (Serota et al., 2010). These additional measures are closely followed in the present study and will be elaborated on in later sections.

Indeed, while "lie scales" are common in psychometric research, they often refer to social desirability measures (e.g., the LIE subscale in the Eysenck Personality Questionnaire; Eysenck & Eysenck, 1975) rather than to validated questionnaires reliably measuring different aspects of deception. Existing developments in lie scales are also often limited to measures that are created and used in studies targeting deception as a dependent or independent variable (as opposed to an exploration of the dimensionality to trait-deception). For instance, Azizli et al. (2016) assessed the tendency to lie in a high-stake deception using the in-house created *Propensity To Lie Questionnaire*. The first part of this questionnaire included questions about the general subjective tendency to lie, while the second part includes items pertaining to two short scenarios describing hypothetical lying situations. The findings reported a relationship between the tendency to lie and antisocial tendencies (Machiavellianism, narcissism, and psychopathy). Unfortunately, this study did not report normative data nor a factor structure analysis of the questionnaire. Similarly, El Haj et al. (2018) created a five-item scale, adapted from the *Impression Management* subscale of the *Balanced Inventory of Desirable Responding* (BIDR; Paulhus, 1991), assessing the tendency to lie (or rather, to impress others), and showed that people with a higher trait tendency to lie have a higher ability to remember to whom they have told a piece of information. More in line with our dimensional approach to trait-deception, Zvi and Elaad (2018) developed the *Lie-Truth Ability Assessment Scale* to measure different facets related to lying, such as the ability to tell lies, to perceive lies, to tell the truth, and also to believe others. Although the factor structure and internal reliability of the scale were not thoroughly tested, the study reported a positive relationship between lying ability and narcissism. Nonetheless, the authors emphasize the need to develop a reliable and valid lie scale.

Using a different approach, Serota and Levine (2015) investigated how participants can be grouped into different "profiles" based on the number of lies they tell per day. They suggested the existence of two distinct groups, everyday liars, the majority of the general population, and prolific liars, who possess a significantly higher tendency to lie and whose dishonest behaviors are often associated with serious matters. This is in line with the studies suggesting that manipulativeness, sociability, anxiousness, and impression management are features related to a stronger self-reported lying ability (Elaad & Reizer, 2015; Gozna et al., 2001; Kashy & DePaulo, 1996; Panasiti et al., 2011). Unfortunately, methodological limitations of the study (the absence of statistically-driven cluster analysis) underline the necessity to further investigate this interesting profile perspective.

One of the challenges for validating a lying questionnaire is the identification of relevant related constructs to assess convergent validity. Although the literature on trait-deception described above is rather sparse, experimental and observational research investigating how deceptive behaviors relate to other inter-individual characteristics can be used as a starting point to establish specific and testable hypotheses. For instance, a large body of research has investigated how lying relates to normal personality traits (Gozna et al., 2001), with evidence suggesting that extraversion is related to a higher lying frequency (Weiss & Feldman, 2006), contrary to conscientiousness which tends to be related to honesty (Gillath et al., 2010). Perceived ability to tell lies shares a positive relationship

with extraversion and openness and a negative relationship with agreeableness (Elaad, 2018; Elaad & Reizer, 2015; Kashy & DePaulo, 1996). The hypothesized underlying link is that people with higher extraversion and openness are more likely to engage in social events, offering more opportunities to lie (Kashy & DePaulo, 1996), which in turn boosts the frequency of - as well as their confidence in - lying. On the other hand, agreeable and conscientious individuals are less likely to lie (and arguably more honest about themselves), consequently describing themselves as being less skilled at it (Gillath et al., 2010).

Another personality dimension related to deception is narcissism (Zvi & Elaad, 2018), a trait commonly found in several personality disorders and one of the facets of the socially malevolent personality profile coined as the "dark triad" (Paulhus & Williams, 2002). Given that narcissists value power and are endowed with a grandiose sense of self, their primary motive to lie is for self-gain and self-enhancement (e.g., portraying themselves in a dominant and attractive fashion; Jonason et al., 2014; Dike et al., 2005). Another possible mechanism at play could be the role of grandiosity in supporting self-deception in the context of negative feedback, which would subsequently facilitate lying to others (Uziel, 2014; Wright et al., 2015).

Naturally, deception is most commonly studied in relationship with antisocial and antagonistic traits, such as psychopathy (Hare & Forth, 1985), which is positively correlated with lying frequency (Halevy et al., 2014), with self-reported lying ability and with the tendency to lie without reason (Jonason et al., 2014). Neuroimaging evidence during a deception task has suggested that specific aspects of psychopathy, namely fearlessness and coldheartedness, were associated with lower activity in the orbitofrontal and temporal cortex, respectively (Fullam et al., 2009). These findings emphasize the potential role of social and emotional sensitivity and control in modulating deceptive behaviors.

More specifically, it is plausible that the relationship between higher-order antisocial traits and deception could be supported by lower-order processes, such as self-control which has been shown to be correlated with the "dark triad" (Jonason & Tost, 2010). This is in line with theoretical and empirical evidence suggesting the implication of cognitive control in lying (Abe, 2009; Debey et al., 2012; Lee et al., 2009; Poletti et al., 2011), supporting processes such as decision-making, taking others' perspectives, maintaining consistency of the fabricated story or inhibiting previously learned content or true responses. This is consistent with neuroscientific findings underlining the role of prefrontal regions in deception (e.g., Christ et al., 2008; Karim et al., 2010) as well as with individuals reporting greater cognitive effort when having to lie as compared to telling the truth (Vrij & Semin, 1996). Nonetheless, as most of the evidence presented above was gathered in experimental settings, it remains unclear how these variables are related to dispositional deception.

Thus, this study aims primarily at investigating the factor and cluster structure of lying as a trait. To achieve these two respective aims, this study explores how questions about lying map onto latent factors related to deception, and whether groups of individuals emerge in the uncovered multidimensional space of deception facets. This will be accomplished through the validation of a short yet reliable questionnaire on the general population, which will allow future deception studies to account for the inter-individual variability in the natural disposition to lie.

In line with the evidence presenting deception as a phenomenon supported by a neurocognitively distributed network of processes, we hypothesized the questions related to deception to preferentially fit a multidimensional structure, composed of different distinct latent factors. Regarding convergent validity, we expect deception to be positively related to malevolent and antisocial traits, such as psychopathy, antagonism, and narcissism. Correspondingly, we also predict a negative link with benevolent traits, such as agreeableness or the recently defined "light triad" traits (Kaufman et al., 2019). A relationship is also expected with normal personality dimensions, such as extraversion, openness and honesty-humility, as well as to traits related to potential deficits of cognitive control, such as impulsivity (Enticott et al., 2006; Fino et al., 2014) and emotion regulation (Kohn et al., 2014; D. Makowski, Sperduti, Lavallée, et al., 2019b; Ochsner & Gross, 2005; Sperduti et al., 2017). Notably, beyond its use as a mere proxy of cognitive control, difficulties in emotion regulation might impact lying in another way, as the engagement in deception might be dependent on one's ability to cope with the emotional states related to lying - e.g., stress - and its consequences - e.g., guilt or shame (Arndt et al., 2013; Carlson & Wang, 2007).

Another aspect of the relationship between emotions and cognitive processes (such as decision making), understudied in the context of deception, is interoception, which refers to one's sensitivity to internal signals and bodily states (Füstös et al., 2012; Garfinkel et al., 2015; Kever et al., 2015). Indeed, decision-making research has shown that individuals with higher interoceptive awareness are less likely to make risky decisions (Dunn et al., 2010; Furman et al., 2013). This is in accordance with the somatic marker hypothesis, in that the accurate detection of physiological arousal guide the use of such interoceptive feedback to make safe, reasoned decisions (Bechara & Damasio, 2005). By extension, since lying could be perceived as a risky behaviour that increases bodily arousal (e.g., de Turck & Miller, 1985), we expect interoception to be related to lying behaviour (for instance, lying frequency or ability).

Methods

The study plan was preregistered (*https://osf.io/3kv7f*). In the spirit of open and honest science, the raw data, as well as the entire analysis script as **Supplementary Materials 1** (including details and additional analyses) can be found at *https://github.com/DominiqueMakowski/2020structure*. An interactive web application to compute the scores of the questionnaire is available at *https://neuropsychology.shinyapps.io/proflier*.

Participants

One thousand and eleven participants from the general population were initially recruited via posters and flyers, as well as online social media platforms (e.g., Facebook). Inclusion criteria included residing in Singapore, as well as an absence of neurological and psychiatric history. Participants were reimbursed 5 Singapore Dollars in cash or vouchers upon survey completion. The study was approved by the Institutional Review Board (Reference Number: IRB-2019-02-026) of Nanyang Technological University (NTU).

Due to the presence of a monetary incentive, as much as to the nature of the investigated construct, a strict procedure was used in order to ensure and maximize data quality. 5 participants were excluded due to missing data, followed by 141 participants with a completion time outside the 90% percentile [< 10.95 min and > 61.94 min]. In addition to completion time (which is considered as the best indicator of data quality, Leiner, 2013), we identified multivariate outliers based on a composite outlier score (see the check_outliers function in the *performance* R package; Lüdecke et al., 2019a, b) obtained via the joint application of multiple outliers detection algorithms (e.g., Mahalanobis distance, Invariant Coordinate Selection, or Local Outlier Factor; see Lüdecke et al., 2019a, b for the full description). This led to the exclusion of 149 participants that were classified as outliers by more than half of the methods used.

The final sample included 716 participants (Mean age = 25.02, SD = 7.07, range = [16.55, 73.51]; 55.87% females; Mean education in years relative to high school completion = 3.54, SD = 1.95, range = [−7, 10]; Mean Religious Engagement = 3.82, SD = 3.09, range = [0, 10]; Mean Religiosity = 4.22, SD = 2.97, range = [0, 10]; Median monthly income per household per capita = SGD 2,000, MAD = SGD 1482.60).

Procedure

Participants completed an online questionnaire created via the Qualtricsplatform. After informed consent was obtained, participants responded to items on visual analog scales or Likert scales (adapted to screen size). Items from 9 existing questionnaires, as well as our Lying Profile Questionnaire (LIE), were included (see below). The presentation order of these 10 inventories was randomized. Note that while items within the LIE inventory were presented in a randomized order, all existing questionnaires were presented following their original validation, and scores for their dimensions were calculated accordingly (by averaging or summing, see **Supplementary Materials 1**). Participants then responded to questions about demographics at the end of the questionnaire. A transcript of the complete survey presentation is available in **Supplementary Materials 2**.

Measures

Lying Based on the theoretical literature and the existing scales on lying, we outlined 3 general domains related to lying relevant for a questionnaire; lying frequency, ability, and accompanying features, such as motives and reactions. From there, we developed an initial pool of items later refined for face validity, ambiguous wording, jargon, or poor phrasing in focus group discussions. The final Lying Profile Questionnaire (LIE) included 44 items phrased in statements such as "I lie more often than most people do" or "I find lying difficult", presented on visual analog scales with "Disagree" and "Agree" as the two extremities. While the LIE items required relative subjective judgments, we also included two questions pertaining to the *Absolute Frequency* of lying (asking how many lies one tells per day and per week). We averaged these two items into one score expressed in lies/day.

We adapted our self-report lie measures in accordance with the methodology used by Serota et al. (2010) to encourage accurate reporting. Prior to recording participants' responses, we provided a definition of lying as encompassing the intent to deceive. This is accompanied with descriptions of different types of lies, making sure to eliminate any instances of disparagement in these presentations. Participants are thus encouraged to consider lies of different magnitude, content (to emphasize that half-truths are also lies), effectiveness, intent (i.e., told for prosocial or antisocial purposes), and consequences. The description is available in **Supplementary Materials 2** (p. 21).

Social Desirability The 16-item Balanced Inventory of Desirable Responding (BIDR-16) self-report questionnaire (Hart et al., 2015) was included to control for related biases in responding such as over-reporting positive traits and under-reporting lying tendencies. This scale includes 2 distinct dimensions, *Self-Deceptive Enhancement* (participants' deception of themselves with a tendency towards positive traits), and *Impression Management* (participants' intention to deceive for the sake of pleasing others).

Psychopathy The 58-item Triarchic Psychopathy Measure self-report questionnaire (TriPM; Patrick, 2010) was used to assess the 3 dimensions suggested by the triarchic model of psychopathy (Patrick et al., 2009), namely *Boldness* (fearlessness, social dominance, and the tendency to engage in adventure-seeking behaviors), *Disinhibition* (the lack of behavioral restrain, manifesting as impulsivity, disregard for social conventions, and aggression) and *Meanness* (the unempathetic and instrumental treatment of others).

Narcissism The short version of the Five-Factor Narcissism Inventory (FFNI-SF; Miller et al., 2013; Sherman et al., 2015) was used to measure 9 specific traits, namely *Acclaim Seeking* (preoccupation with achieving acclaim, status, and/or fame), *Entitlement* (expectations of special and self-serving treatment), *Need for Admiration* (excessive need for the admiration and approbation of others), *Manipulativeness* (a disposition to deceptively manipulate the feelings and/or opinions of others), *Lack of Empathy* (failure to be aware of, appreciate, or acknowledge the feelings of others), *Indifference* (lack of self-consciousness or self-doubt in response to criticism or rebuke), *Thrill Seeking* (excessive excitement-seeking that leads to high-risk behavior for the sake of thrills and excitement), *Distrust* (maladaptive low level of trust concerning the intentions and motivations of others), and *Exploitativeness* (a disposition for instrumental treatment of others, i.e., to exploit or take advantages of others).

Normal Personality The 24-item measure of the Big-Six personality dimensions (Mini-IPIP6; Sibley et al., 2011) was used to measure the Big Six "normal" (as opposed to pathological) personality traits based on the HEXACO Personality Model (Ashton & Lee, 2009), namely *Extraversion* (the tendency to engage in social behaviors such as exhibiting leadership and sociability), *Openness* (the extent to which one is open-minded in terms of imagination and curiosity), *Agreeableness* (how cooperative and tolerant one is of others, with individuals high on this trait often being perceived as warm, forgiving, and kind), *Conscientiousness* (being diligent, meticulous and organized during task execution), *Neuroticism* (the tendency to experience a persisting negative emotional state), and *Honesty-Humility* (being honest, sincere, and fair during social exchanges).

Pathological Personality The 25-item Personality Inventory for DSM-5 Brief Form (PID-5-BF) was used to assess 5 pathological personality traits (Al-Dajani et al., 2016; Hopwood et al., 2012), namely *Negative Affect* (the frequency and intensity of negative emotional experiences such as anxiety, anger, and depression), *Detachment* (social withdrawal and diminished affective experiences), *Antagonism* (manipulativeness, deceitfulness, callousness and hostility) *Disinhibition* (engagement in impulsive behaviors for immediate gratification), and *Psychoticism* (eccentric or incongruent behaviors and cognitions, such as hallucinations and delusions).

Light Triad The 12-item Light Triad Scale (LTS; Kaufman et al., 2019) was used to measure prosocial and morally positive traits (as opposed to antisocial or antagonistic ones), including *Faith in Humanity* (the belief and trust that individuals are fundamentally good in nature), *Humanism* (the extent to which one places value on the dignity and worth of others), and *Kantianism* (the treatment of individuals as means to themselves rather than using them instrumentally).

Impulsivity The 20-item Short UPPS-P Impulsive Behaviour Scale (Cyders et al., 2014; Whiteside & Lynam, 2001) was used to measure 5 facets of impulsivity, namely *Negative Urgency* and *Positive Urgency* (one's propensity to act impulsively under negative and positive emotional states, respectively), *Lack of Perseverance* (the inability to focus on tasks of a boring or difficult nature), *Lack of Premeditation* (the propensity to act without thinking), and *Sensation Seeking* (the inclination towards partaking in novel and thrilling experiences).

Emotion Regulation The 18-item Difficulty in Emotions Regulation Scale (DERS; Victor & Klonsky, 2016) was used to measure 6 facets of emotion regulation deficits, namely *Awareness* (lack of recognition and appreciation of one's emotions), *Clarity* (difficulties in giving meaning to emotions), *Goals* (difficulties in engaging in goal-directed cognition and behavior when distressed), *Impulse* (lack of control when distressed), *Non-Acceptance* (unwillingness to accept certain emotional responses), *Strategies* (lack of access to strategies for feeling better when distressed).

Interoception We used 11 items from the Multidimensional Assessment of Interoceptive Awareness, Version 2 (MAIA-2; Mehling et al., 2018) to specifically measure 2 facets of interoception, namely *Noticing* (the conscious awareness of bodily sensations), and *Body Listening* (he ability and tendency for active listening to the body for insight).

Demographic Participants provided demographic information related to their *Education* (highest academic qualification achieved or the qualification they are currently pursuing), *Sex*, *Age*, and their socio-economic status (SES) which was operationalized as the average monthly household *Income* per capita. Additionally, two items related to religious *Faith* were presented on Likert scales, pertaining to how religious the participants perceive themselves to be and how actively engaged in religious activities they are.

Data Analysis

We started by investigating the factor structure of our initial set of items. We randomly split the study sample into a training set (60%) and a test set (40%). Exploratory Factor Analysis (EFA) was carried out with the training set to explore the scale's underlying factor structure and Confirmatory Factor Analysis (CFA) was performed with the test set to test the goodness-of-fit of the suggested factor structures. We then examined the cluster structure using k-means clustering and assessed the convergent validity with partial correlation analysis.

Data processing was carried out with R (R Core Team, 2019) and in particular the *psych* (Revelle, 2018) and the *lavaan* (Rosseel, 2012) packages, as well as the *easystats* ecosystem (Lüdecke et al., 2019a, b; Makowski et al., 2019b, c; Lüdecke et al. 2020). The raw data, as well as the full reproducible analysis script (along with complementary results and figures), are available in **Supplementary Materials 1**.

Results

Factor Structure

The 44 initial items were deemed suitable for factor analysis (KMO = 0.93; Bartlett's test of sphericity $\chi^2(946) = 9653.38$, $p < .001$). The factor number exploration using the method agreement procedure (see the n_factors function in the *parameters* package; Makowski et al., 2019b, c) suggested 2 optimal factor solutions: four factors, and one latent factor, respectively accounting for 43.00% and 24.63% of variance of the dataset. Hence, we submitted the unique one-factor and four-factor models to Confirmatory Factor Analysis (CFA).

The confirmatory factor analysis favoured the four-factor solution over the one-factor. We then compared the four-factor solution with the initial hypothetic model with which we built the scale, which favoured the four-factor model. Finally, we compared the full four-factor model (including all items) with short forms retaining only the 3, 4 or 5 most loading items for each of the 4 dimensions. The 3-items version outperformed all versions, including 5-items and 4-items. Nonetheless, as 3-items per construct is the bare minimum for adequate reliability, we decided to keep the second best performing version with 4-items per factor, which also displayed excellent indices of fit (see Table 1).

The final version of the LIE questionnaire assesses 4 latent dimensions measured with 4 items each (16 items in total). Based on the most loading items (see Table 2), we labeled these factors *Ability* (representing one's subjective ability and ease to create and deliver believable lies), *Frequency* (representing one's subjective and relative assessment of lying frequency), *Negativity* (the unwillingness to lie related to negative internal factors such as moral values and/or emotional reactions associated with lying) and *Contextuality* (the flexible and context-driven willingness to lie depending on external factors such as stakes, necessity and alternative options). These factors were significantly correlated together (see Fig. 1), with *Ability*, *Frequency* and *Contextuality* showing positive relationships, and *Negativity* being negatively associated with them. We back-fitted the CFA model on the full dataset in order extract individual factor scores.

In line with recent recommendations, we assessed the multidimensional reliability by means of omega coefficients (Green & Yang, 2015; Watkins, 2017), suggesting in general a high reliability of the 16 items ($\omega_{total} = 0.83$) as well as for each dimension ($\omega_{total}^{Ability} = 0.87$; $\omega_{total}^{Frequency} = 0.91$; $\omega_{total}^{Contextuality} = 0.75$; $\omega_{total}^{Negativity} = 0.76$). Importantly, the analysis confirmed that the 4 dimensions cannot be considered as only reflecting a unique underlying general factor ($\omega_{hierarchical} = 0.36$).

Cluster Structure

We investigated the presence of higher-density regions in the four-dimensional space of the LIE factor structure. The dataset was deemed suitable for clustering (Hopkins' H = 0.24), and the method agreement procedure (aggregating 28 methods to estimate the optimal number of clusters; see **Supplementary Materials 1**), supported the existence of 2 (8/28) or 3 (11/28) clusters. We then applied k-means clustering, which revealed that grouping the participants in 2 and 3 clusters would account for 44.92% and 57.58% of the total variance of the four dimensions of the questionnaire, respectively. Thus, we decided to go ahead with the latter solution and assign each participant to its nearest cluster (see Fig. 2), labeling them as *Average* (41.86% of the sample; people that report an average lying ability, slightly lower than average frequency, average negativity and contextuality), *Trickster* (35.04% of the sample; people with high reported lying ability, frequency, low negative experience associated with deception and above-average flexibility in its implementation), and *Virtuous* (23.10% of the sample; people with very low reported lying ability and frequency, strong negative emotions and moral attitude associated with lying and high rigidity in their (non-)usage of deception).

Convergent Validity

Bayesian Regressions (from which we will report the 89% Credible Interval (CI) and the probability of direction *pd*, a Bayesian equivalent of the *p* value; see Makowski et al., 2019b, c), using both the LIE dimensions and profiles were used to assess the role of demographic variables, and Gaussian Graphical Models (GGMs; Epskamp et al., 2018), i.e., networks based on partial correlations, were used to assess the

Table 1 CFA fit indices of the full four-factor model, one-factor model, hypothesized model, and the short-form four-factor models (containing 3, 4, and 5 loading items per dimension respectively)

Model	AIC	BIC (adj.)	Chi2	RMSEA	CFI	SRMR
Four Factors: all items	57,650.70	57,702.29	2142.547	0.068	0.821	0.089
One Factor: all items	59,691.09	59,739.39	4194.940	0.109	0.527	0.122
Hypothesized: all items	58,197.46	58,247.40	2695.311	0.081	0.742	0.097
Four Factors: 3 items	15,296.48	15,312.94	117.046	0.069	0.960	0.061
Four Factors: 4 items	20,309.91	20,330.76	223.804	0.065	0.949	0.061
Four Factors: 5 items	25,408.64	25,433.89	322.178	0.056	0.949	0.061

links between the LIE dimensions and other theoretically related constructs. As the details of the analyses are available in **Supplementary Materials 1**, we will only report in the manuscript the significant links (Bonferroni corrected and $p < .001$ for the GGMs to control for spurious links).

Demographics

Sex We fitted two Bayesian logistic regressions to predict Sex with the lying profile (offering a simpler combined and integrated perspective), and the 4 lying dimensions (to assess the underlying driving effects independently of one another). These revealed that men, as opposed to women, were more likely to be Tricksters than Average (coefficient = 0.41, 89% CI [0.13, 0.67], pd = 99.15%) as well as more likely to be Average than Virtuous (coefficient = −0.48, 89% CI [−0.81, −0.19], pd = 99.38%). This effect was likely to be driven by Ability, the only dimension significantly sensitive to sex (coefficient = 0.14, 89% CI [0.07, 0.21], pd = 99.85%), reported as higher by men than by women.

Age The Bayesian linear mixed models predicting *Age* were adjusted for *Sex* (entered as random factor), *Income* and *Education* (entered as fixed effects). *Age* was higher for the *Virtuous*, relative to the *Average* profile (coefficient = 2.81, 89% CI [1.68, 4.01], pd = 100%). These differences were likely driven by *Ability* which was negatively related to *Age* (coefficient = −0.36, 89% CI [−0.60, −0.13], pd = 99.17%), suggesting that younger people tend to portray themselves as good liars.

Socio-Economical Status The Bayesian linear mixed models predicting *Income* were adjusted for *Sex* (entered as random factor), *Education* and *Age* (entered as fixed effects). Although the profiles were not different in terms of *Income*, *Ability* was the only dimension significantly and positively related to *Income* (coefficient = 189.56, 89% CI [28.94, 342.75], pd = 97.12%).

Education The Bayesian linear mixed models predicting *Education* were adjusted for *Sex* (entered as random factor) and *Age* (entered as fixed effects). *Education* was higher for the *Virtuous* (coefficient = 0.36, 89% CI [0.08, 0.61], pd = 98.62%) and lower for *Trickster* (coefficient = −0.36, 89% CI [−0.58, −0.12], pd = 99.52%), both relative to the *Average* profile. No dimension was significantly related to *Education*.

Faith Due to their strong correlation (r = 0.86, $p < .001$), we collapsed the two religion-related items into one *Faith* variable. The Bayesian linear mixed models predicting *Faith* were adjusted for religion type (entered as a random factor). *Faith* was stronger for the *Virtuous*, relative to *Average* profile (coefficient = 0.67, 89% CI [0.34, 1.05], pd = 99.85%) and weaker for *Tricksters* relative to the *Average* (coefficient = −0.37, 89% CI [−0.68, −0.07], pd = 97.42%). This effect was likely driven by the fact that all lying dimensions - except *Ability* - were associated with *Faith*. Stronger *Faith* was related to higher *Negativity* (coefficient = 0.53, 89% CI [0.38, 0.68], pd = 99.98%), lower *Contextuality* (coefficient = −0.25, 89% CI [−0.37, −0.12], pd = 99.98%) and higher *Frequency* (coefficient = 0.25, 89% CI [0.14, 0.36], pd = 100%) (see Fig. 3).

Absolute Lying Frequency The Bayesian linear models predicting absolute lying frequency (in lies told per day; adjusted for social desirability) revealed that *Tricksters* reported a higher (coefficient = 0.51, 89% CI [0.39, 0.64], pd = 100%), and the *Virtuous* a lower (coefficient = −0.35, 89% CI [−0.49, −0.22], pd = 100%) absolute lying frequency than the *Average*, respectively. Specifically, the dimensional model suggested that relative *Frequency* (coefficient = 0.17, 89% CI [0.13, 0.21], pd = 100%), as measured by the questionnaire, was significantly predicting the absolute *Frequency* of lies told per day (see Fig. 4).

Social Desirability The GGM network suggested that *Self-Deceptive Enhancement* was positively associated with reported lying *Ability* (r = 0.21, 95% CI [0.14, 0.28]) and negatively with lying *Frequency* (r = −0.20, 95% CI [−0.27, −0.13]). On the other hand, active *Impression Management* was positively associated with *Negativity* (r = 0.12, 95% CI [0.05, 0.19]) and negatively with *Frequency* (r = −0.13, 95% CI [−0.20, −0.06]) and *Contextuality* (r = −0.17, 95% CI [−0.24, −0.10]). The relationship between lying *Frequency* and *Contextuality* also changed from positive (in the previous analyses) to negative (r = −0.17, 95% CI [−0.23, −0.10]).

Table 2 All initial item loadings from the Exploratory Factor Analysis (EFA). The final item selection (the 4 most loading items of each dimension) also has the corresponding regression coefficients from the Confirmatory Factor Analysis (CFA) model that were used to calculate individual scores (between brackets)

Item	Label	Frequency	Ability	Negativity	Contextuality
Q4	I have a tendency to lie	0.75 [1.01]	0.17	−0.17	0.05
Q23	I find it difficult to refrain myself from lying	0.73 [0.82]	0.11	−0.15	0.00
Q5	I lie more often than most people do	0.73 [0.92]	0.18	−0.24	0.00
Q1	I lie frequently	0.70 [1.00]	0.18	−0.3	0.15
Q22	I find myself lying without any reason	0.68	0.06	−0.14	0.00
Q7	I lie more than I think I should	0.67	0.05	−8.44E-03	0.11
Q6	I lie more frequently than what I expect myself to	0.65	0.1	−0.08	0.11
Q2	I lie in many situations	0.61	0.18	−0.34	0.09
Q26	I enjoy lying	0.59	0.23	−0.24	−0.03
Q8	Others lie less often than I do	0.53	0.14	−0.11	0.02
Q29	I lie whenever it's convenient	0.49	0.18	−0.18	0.25
Q21	I have to try hard to avoid lying	0.45	−0.04	0.09	−0.08
Q31	I lie if it's the most direct way to get what I want	0.44	0.12	−0.12	0.31
Q28	I feel satisfied when others believe my lie	0.36	0.24	−0.12	0.3
Q24	It is easy to hold back from telling lies	−0.29	0.09	0.15	0.06
Q10	I can lie well	0.25	0.82 [1.05]	−0.14	0.21
Q9	I am a good liar	0.3	0.75 [1.00]	−0.17	0.18
Q18	It is easy for me to make up clever lies	0.25	0.73 [0.87]	−0.11	0.16
Q14	It is hard for others to detect my lies	0.15	0.73 [0.77]	−0.03	0.18
Q11	I am good at deceiving others	0.33	0.71	−0.11	0.14
Q13	Others can easily tell when I'm lying	0.11	−0.69	0.19	−0.06
Q12	I can lie effectively if I want to	0.13	0.67	−0.04	0.27
Q17	I find lying difficult	−0.08	−0.67	0.42	−0.14
Q15	I almost never get caught lying	0.08	0.65	−0.07	0.25
Q20	I do not have to prepare much for a lie	0.22	0.58	−0.13	0.16
Q19	I find it taxing to come up with a good lie	−0.06	−0.49	0.36	0.07
Q27	I feel tense whenever I have to lie	−0.03	−0.49	0.44	0.04
Q16	My lies often arouse suspicion from others	0.28	−0.46	0.11	−0.13
Q41	Lying is against my principles	−0.19	−0.23	0.62 [1.30]	−0.19
Q34	I always avoid lying if I can	−0.41	−0.05	0.57 [0.86]	0.06
Q44	It is bad to lie	−0.13	−0.21	0.55 [1.07]	−0.17
Q25	I feel guilty after lying	−0.08	−0.3	0.54 [1.00]	−0.09
Q36	I prefer to tell the truth even if it gets me into trouble	−0.2	−0.12	0.46	−0.13
Q35	I would only lie if I have no other choice	−0.12	0.01	0.36	0.32
Q37	I would never lie for trivial matters	−0.15	−0.03	0.34	0.02
Q38	I would never lie in serious contexts	−0.11	−0.1	0.31	−0.01
Q43	It is okay to lie sometimes	0.07	0.16	−0.21	0.71 [1.21]
Q33	I lie when necessary	0.08	0.18	−0.02	0.69 [1.00]
Q42	It is acceptable to lie depending on the context	0.02	0.25	−0.1	0.62 [1.03]
Q39	I would lie if something important was at stake	0.02	0.18	0.05	0.47 [0.78]
Q40	I would only lie if it is harmless	−0.06	0.1	0.09	0.46
Q30	I lie when it's easier than telling the truth	0.32	0.04	−0.08	0.38
Q32	I lie when telling the truth is too troublesome	0.32	0.00	−0.15	0.38
Q3	I never tell lies	0.03	−0.13	0.26	−0.32

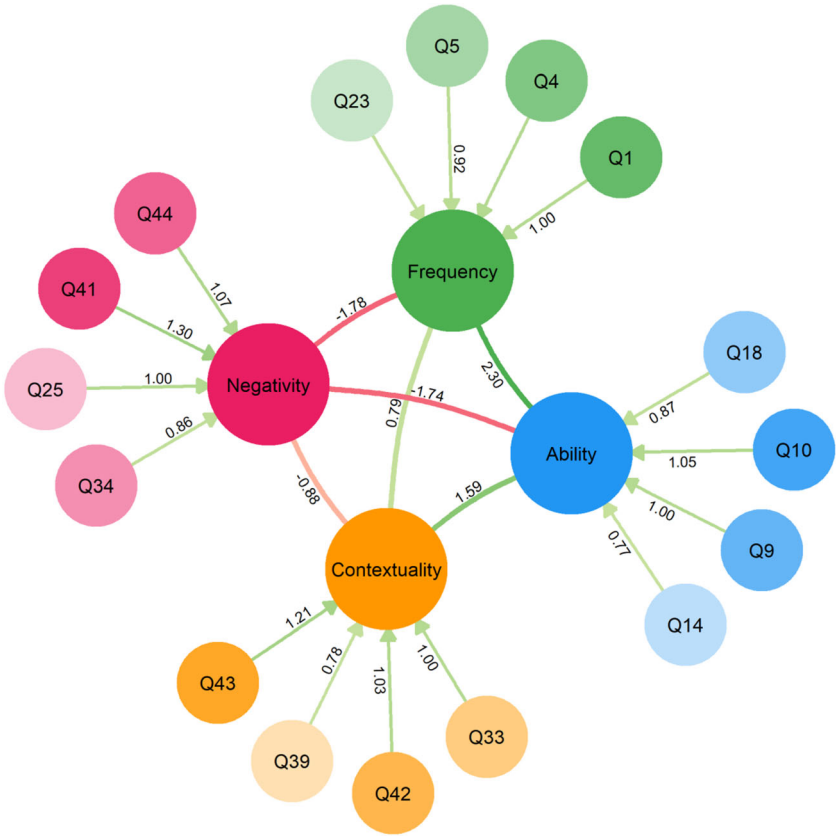

Fig. 1 Confirmatory structure of the deception scale items and the correlation between the latent factors. Red links represent negative correlations and green links represent positive correlations. The green arrows represent the loadings of the items onto their respective factors. The numbers correspond to the regression coefficients from the Confirmatory Factor Analysis (CFA)

Psychopathy To avoid contamination of the following models by previously identified mediators, we adjusted LIE scores by regressing out social desirability, age and sex. The GGM network investigating the relationship with psychopathy suggested that lying *Ability* was positively associated with *Boldness* (r = 0.23, 95% CI [0.16, 0.30]), that *Frequency* was positively associated with *Disinhibition* (r = 0.23, 95% CI [0.17, 0.30]) and that *Negativity* was negatively associated with *Meanness* (r = −0.19, 95% CI [−0.26, −0.12]) but also positively with *Disinhibition* (r = 0.15, 95% CI [0.08, 0.22]).

Narcissism The GGM network suggested that lying was mainly associated with three core components of narcissism. Lying *Ability* was positively associated with *Manipulativeness* (r = 0.35, 95% CI [0.29, 0.43]). *Negativity* was negatively associated with *Exploitativeness* (r = −0.13, 95% CI [−0.20, −0.05]).

Normal Personality The GGM network suggested that lying was mainly associated with two dimensions of normal personality. Lying *Ability* was positively associated with *Openness* (r = 0.15, 95% CI [0.08, 0.22]). Lying *Negativity* was negatively associated with *Honesty/Humility* (r = −0.15, 95% CI [−0.22, −0.08]).

Pathological Personality The GGM network suggested that lying was mainly associated with two dimensions of pathological personality. Lying *Ability* was positively associated with *Antagonism* (r = 0.19, 95% CI [0.12, 0.26]) and *Frequency* was positively associated with *Disinhibition* (r = 0.13, 95% CI [0.05, 0.20]).

Light Triad The GGM network suggested that lying was independent of the Light Triad facets.

Impulsivity The GGM network suggested that lying *Frequency* was positively associated with *Positive Urgency* (r = 0.16, 95% CI [0.09, 0.23]) and that *Negativity* was negatively associated with the *Lack of Premeditation* (r = −0.15, 95% CI [−0.21, −0.08]).

Emotion Regulation The GGM network suggested that lying *Frequency* was positively associated with deficits of *Impulse* control in emotional contexts (r = 0.13, 95% CI [0.05, 0.19]).

Interoception The GGM network suggested that lying was independent of the sensitivity to bodily signals.

Discussion

This study aimed at investigating the structure of dispositional deception and its personality correlates by validating a lying

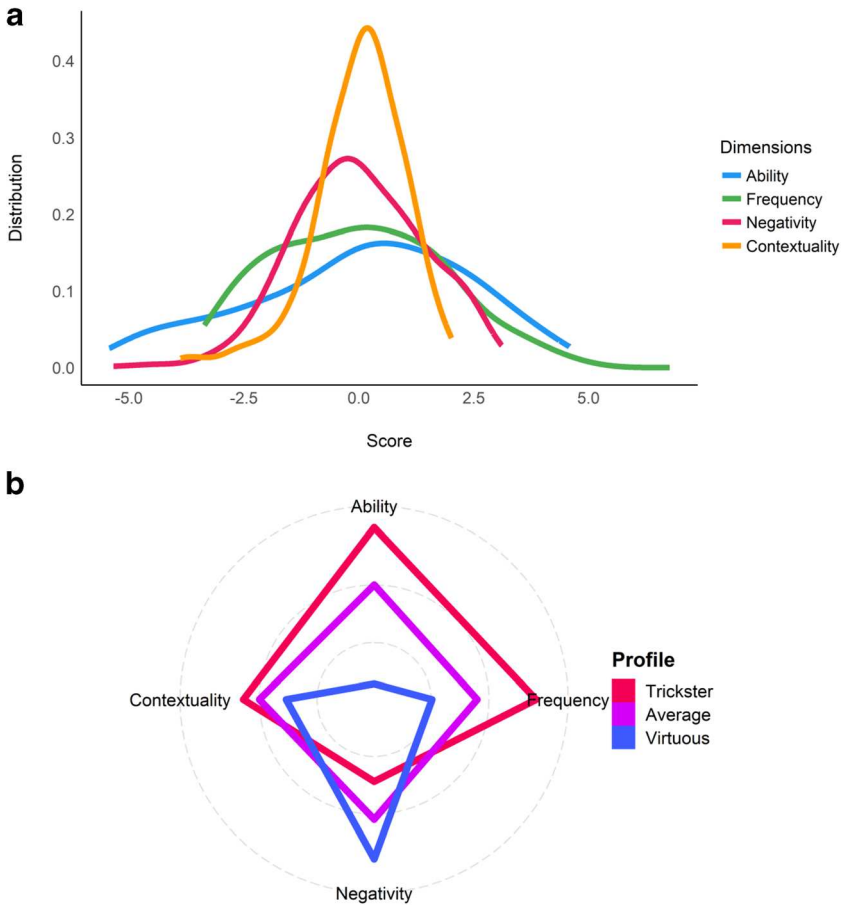

Fig. 2 The distribution of the LIE dimensions (A) and the centre values of the 3 clusters of participants

questionnaire on a diverse sample. Using a cognitive perspective, we attempted to decompose lying as a high-level phenomenon, and explore the distinct underlying mechanisms that contribute to it. Our findings suggest that deception, taken as a trait, comprises of four latent dimensions, namely ability (the reported proficiency and ease to create and deliver believable lies), frequency (the reported tendency to lie), negativity (the negative perception of lying related to internal factors, such as emotions or moral values), and contextuality (flexibility of one's willingness to lie related to external factors such as stakes, necessity or alternative options). Although this multi-dimensionality was shown to be robust and reliable, the consistent residual inter-correlation between the four dimensions is nonetheless be compatible with the existence of an underlying over-arching general factor. Such general inclination towards lying also manifests in the existence of distinct lying profiles, i.e., clusters of specific patterns of the dimensional structure. This, in turn, underlines the specificity and distinctiveness of lying as a phenomenon, suggesting its conceptualization as a special action and context that requires, triggers and recruits a specific combination of - and interaction between - a specific set of distinct general-purpose mechanisms. In other words, the different facets of lying share a common core component that is specific to its object and purpose. Thus, it appears that deception can hardly be reduced to the sum of its underlying mechanisms, and that a global perspective is required to appropriately capture this phenomenon.

Importantly, we also investigated how these facets of deception are related to other dispositional characteristics (Fig. 5). In line with our hypotheses, we found a significant relationship with antisocial traits. Specifically, individuals presenting with antagonistic attributes, such as meanness, boldness and manipulativeness reported high deception abilities, deception frequency and low negativity related to lying. Though the negative relationship between meanness and negativity was unexpected, a likely explanation is that individuals who score high on antisocial traits confer less reliance on moral principles when making the decision to lie or have less negative emotional reactivity towards lying, which translates into greater ease when lying.

We were initially expecting to find the opposite relationship with markers of a benevolent nature. However, under our stringent statistical criteria, we found no significant relationship between deception and pro-social traits. This is in line with recent studies showing a relative independence of benevolence traits in relation to malevolent traits (Kaufman et al., 2019; Tortoriello & Hart, 2019), or a more complex and subtle pattern of the relationship between the (seemingly) opposite extremes of human nature.

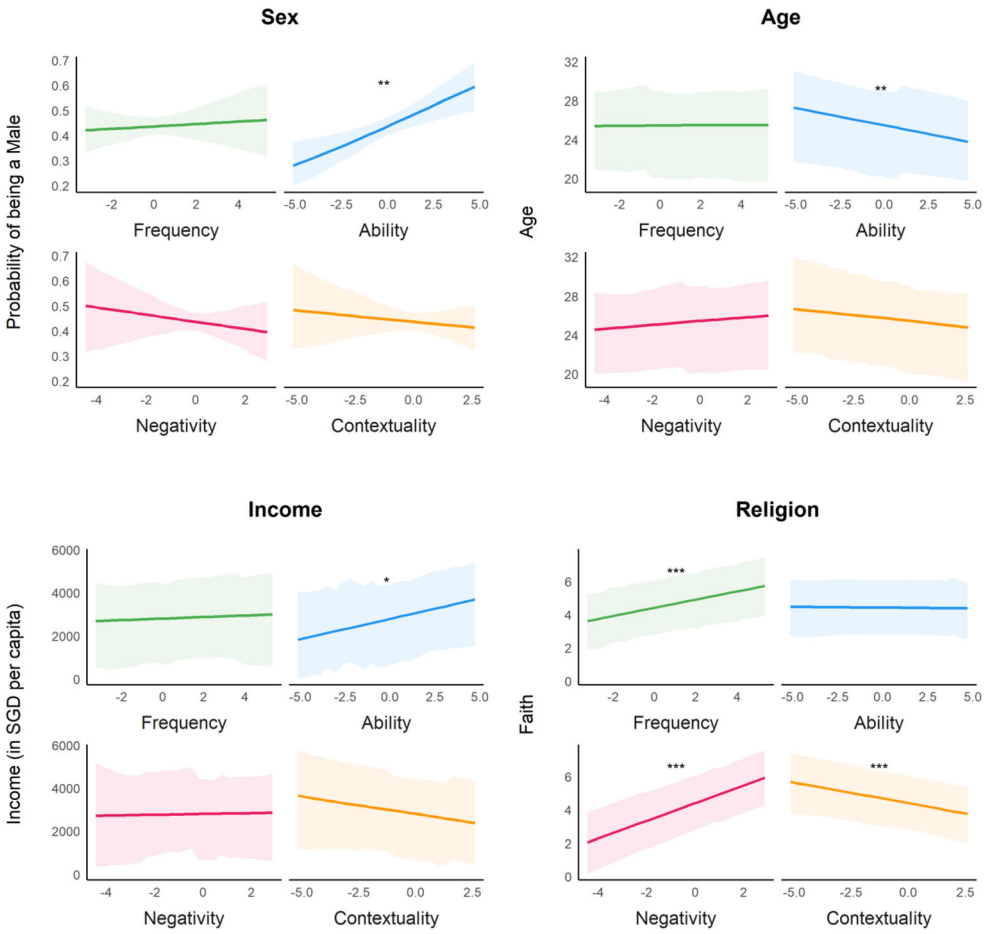

Fig. 3 The linear relationship between lying dimensions and demographic variables. Asterisks represent effects with a significant probability of existence (° > 95%, * > 97%, ** > 99%, *** > 99.9%)

For instance, narcissism, traditionally considered as one of the pillars of antisociality, has been found to show an independent, positive correlation to benevolent traits (Kaufman et al., 2019). Aside from further challenging the notion of a clear and relevant dichotomy between so-called "dark" and "light" sides of personality, our findings suggest that a pro-social attitude and nature can co-exist with all types and forms of dispositional deception.

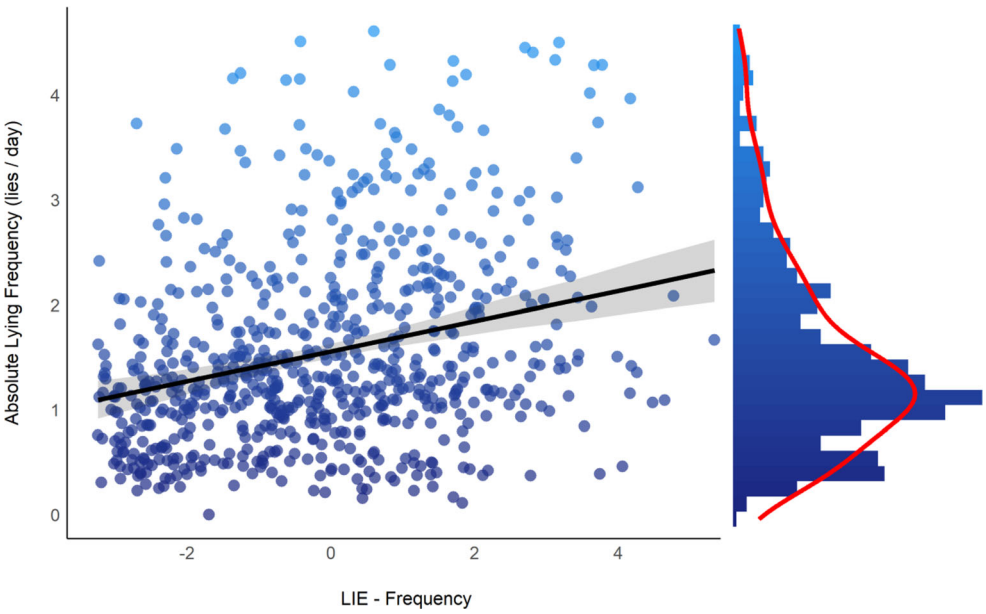

Fig. 4 The relationship between the reported absolute frequency (the number of lies told per day, which distribution is showed on the right) and the Frequency dimension of the questionnaire

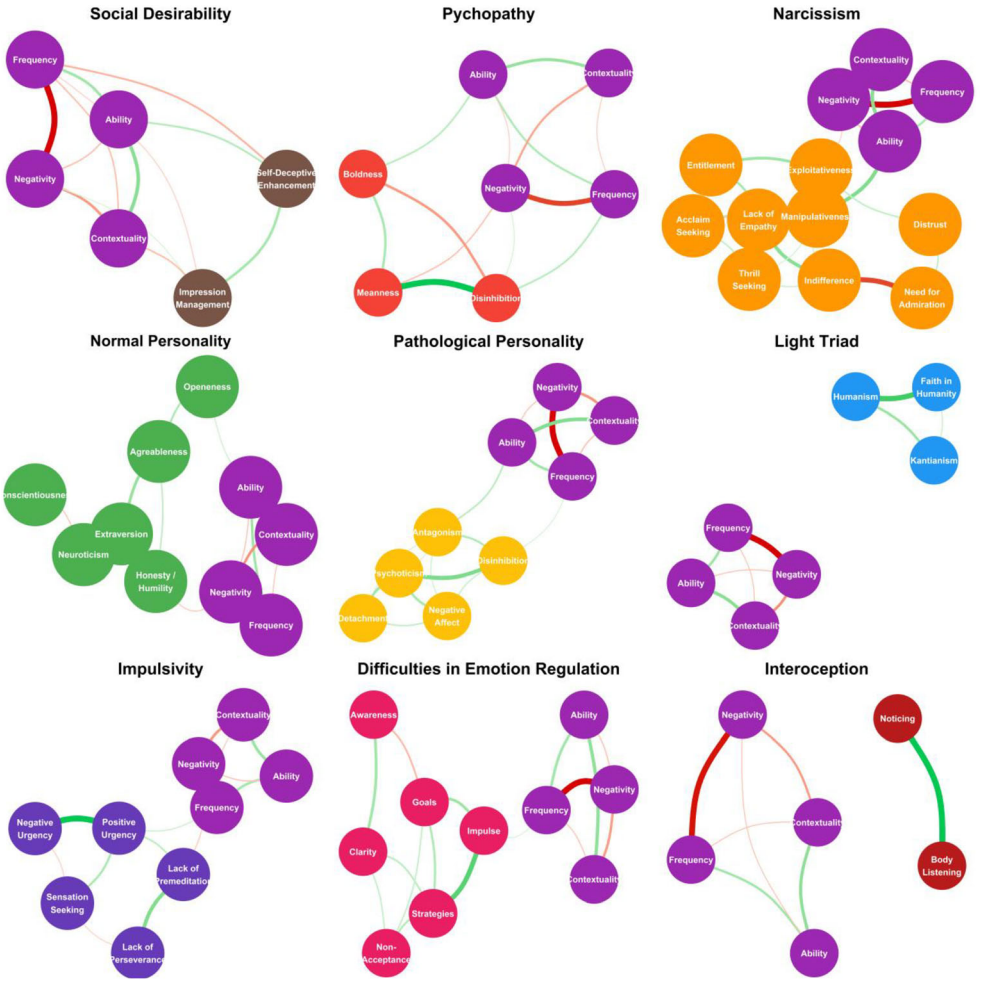

Fig. 5 Gaussian Graphical Models (GGMs) for convergent validity with other constructs. The relationships with the lying dimensions were, for all networks except the first, adjusted for social desirability, age and sex. Red and green links represent negative and positive correlations, respectively

Our study also confirmed links with specific dimensions of normal personality. In particular, lying ability was positively related to one's openness to experiences. This link might be mediated by the increased tendency of exposure to complex, new and uncertain contexts, such as social situations, that would in turn create more opportunities for lying (e.g., for preserving others' impression of themselves), thus nurturing confidence in one's ability to lie. However, we also found honesty-humility to be negatively associated with negative perceptions of lying. Though this link might appear contradictory initially, one possible explanation is that individuals with strong honest-humility traits tend to approach deception with a more neutral stance. They may circumvent any moral judgment that typically comes with it, cooperating genuinely with others even in situations where they have been exploited and/or lied to. Their sincerity and honesty may drive them to perceive deception as an objectively common phenomenon with no intrinsic nor absolute moral value.

One striking finding of the present study is the relationship between specific aspects of dispositional deception and markers of cognitive control (more exactly, proxies of cognitive control deficits). We showed that individuals with difficulties in cognitive control tend to have a higher lying frequency, indicating the involvement of executive functions (e.g., inhibition and flexibility) in the controlled delivery of lies and manipulation of reality. Importantly, this pattern was consistently found across different measures, such as impulsivity, emotion regulation deficits, and disinhibited behavior. Further and more direct investigations of the differential role of executive functions in deception are necessary to cast more direct light on the mechanisms at stake.

Interestingly, a facet of impulsivity, namely the lack of premeditation was inversely related to negative perceptions of lying. These traits implicate one's ability to plan lies systematically and focus their attention on the the task of lying. This result suggests that the ability to consider the emotional and practical implications of one's actions plays a significant role in deception. A greater tendency to weigh the consequences of lying enhances perceptions of negativity towards lying as an act, as lying can be cognitively and emotionally overwhelming. However, while we would have expected such negative perceptions to be more pronounced in individuals

with low emotion regulation skills and high interoceptive sensibility, we found no evidence in favor of this hypothesis. Nevertheless, it is important to note that embodied constructs, such as interoceptive and emotion regulation abilities, are only partially measured via self-reported questionnaires (Barrett et al., 2004; Garfinkel et al., 2015). Thus, we suspect that the tools used in the present study were not sufficiently sensitive, or simply not appropriate, which prevents us from drawing any definite conclusions regarding the absence of associations between these dimensions. Future studies should investigate the role of such embodied aspects of cognition through more direct means.

Finally, we emphasize the importance of measuring - and controlling for - social desirability when attempting to measure morally or socially loaded constructs, such as lying, through self-reported questions. Our findings suggest a strong yet subtle relationship, revealing that individuals who perceive themselves more favorably rated themselves as better, yet less frequent, liars. Additionally, people who tend to consciously and actively portray themselves in a socially desirable manner are both more likely to report stronger negativity towards lying and being less influenced by external factors in their decision to lie. In line with this pattern, they also report lying less frequently, which can be observed using different types of measures, such as the absolute frequency of lying (i.e., the number of lies told a day). It is interesting to note that after controlling for social desirability, the relationship between lying frequency and context-driven willingness to lie shifted from positive to negative. Consistent with our other results, we suggest that a common cognitive basis might be driving this relationship. In particular, cognitive control, which allows and supports the control and inhibition over the tendency to lie, would also be necessary for facilitating flexible and context-driven usage. Thus, people who tend to lie a lot in general also use this strategy in a less parsimonious and adaptive manner.

Importantly, we found that lying behavior is also modulated by demographic variables. Consistent with previous findings (Elaad, 2018), individuals who are male and have a higher income reported a higher ability to lie. This concurs with research showing that malevolent traits are negatively associated with being female and income (Kaufman et al., 2019). The age- and sex-related links with honesty, social desirability, and boldness, as well as the relationship between income and self-control (Duckworth, 2011; Moffitt et al., 2011), are likely to mediate such effects.

In addition, we found that people with high religiosity tend to perceive lying as intrinsically negative (possibly related to more absolute or immanent moral values) and are less pressured by the external context necessitating lying (suggesting a stronger role of these moral values). However, our findings also suggest that religiosity is positively correlated with lying frequency. Although surprising, this effect could be mediated by an increased honesty of religious people, as well by the fact that the greater negativity (and therefore saliency) of lies enhances the encoding and ease of retrieval of these events, leading in turn to an overestimation of their frequency.

Limitations and Future Directions

It is important to note that lies are not all alike and that different types exist, from "harmless" white lies in daily social interactions to more serious and high stakes attempts, for instance to conceal an act of law violation. Moreover, lying is arguably not, in most cases, the end goal but rather the means to attain given goals, which vary extensively across the population. Lying types and motives, although not the focus of the present study, are potentially relevant aspects to gain a comprehensive understanding of this phenomenon. However, one of the main challenges of investigating lying motives is the validation of a robust and usable framework for the classification of lies. For instance, Weber (2017) suggested the existence of 11 types of lies while Zvi and Elaad (2018) emphasized 3 motives (self-gain, altruism, and lying for no reason). Their study further shows that vanity and exhibitionism, two facets of narcissism, were respectively predictive of self-beneficial lies and lying for no reason. Though exploring deception-related motivations is beyond the scope of the present study, these previous findings suggest that the extent of one's motivation to lie (and the type of motive) might be sensitive to personality traits, supporting its relevance within a dispositional approach to deception. This serves as a potential avenue of exploration for studies to further delineate the mechanisms involved in deception.

Another interesting and complementary approach could focus on the reception of lies, rather than how individuals perceive themselves as liars. Prior work suggests that extroverts are more proficient at telling lies as well as detecting lies (Elaad & Reizer, 2015), and that frequent liars are more likely to perceive themselves as good lie detectors (Zvi & Elaad, 2018), underlining this issue as a promising topic for investigation.

Though the present study did not aim at study cultural determinants or inter-cultural differences in deception, we also acknowledge the possible role of population-related characteristics in influencing our results. In this context, it is important to highlight that many psychology studies, including task and questionnaire validations, have been criticized for their over-representation of a biased subset of participants (referred to as "WEIRD" samples - Western Educated Industrialised Rich and Democratic; Henrich et al., 2010). The demographics of our Singapore sample is not only predominantly non-western, but is diverse in terms of age, SES, ethnicity, culture and religion (Singapore being a multicultural and multiethnic society), which constitutes a unique strength of the present study. That said, the possible sample-related specificities warrant extra caution on any claims of generalization, as the conceptualization of lying may

vary across cultural norms. In most of deception research using WEIRD samples, where self-interest is at the core of decision-making, lying is perceived as a strategic choice to achieve personal goals (Rodriguez, 1996). On the other hand, members of collectivistic communities are comparatively more motivated by their social obligation to group members (e.g., lying to help other members 'save face'; Gudykunst et al. (1988)) (Rodriguez, 1996). The motivation to lie, and hence the context in which lying occurs, is thus very much dependent on one's cultural identity. As we did not measure specifically culture-dependent constructs, we cannot preclude the possibility that a different population may give rise to differences. It is thus critical that future studies investigate intercultural differences and carry out a cross-cultural validation of the structure of deception.

Finally, it is crucial to corroborate questionnaire scores with actual behavior (Serota et al., 2010) to support the validity of such self-reported measures. However, behavioral experiments have been lacking in ecological validity due to paradigms that fail to elicit realistic lying from participants in a way that is self-motivated and spontaneous (e.g., participants are sometimes instructed to lie). The use of games with monetary incentives seems to be a promising approach to investigate whether actual lying behaviors are consistent with self-reported measures of lying (Levine et al., 2010).

In conclusion, this study attempted to investigate the trait-like aspect of deception. On a theoretical level, our findings underline lying as a specific yet multi-faceted phenomenon, related to (and modulated by) a variety of inter-individual characteristics. On a practical level, the brief questionnaire validated in this study will allow for including this measure in future experiments on deception to obtain a more complete and accurate picture of its behavioral and neural correlates. Nevertheless, further investigation is warranted to understand how lying behavior varies across different motivating factors, contexts and implications, as well as specific populations defined by factors like culture, pathology, and criminality.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s12144-021-01760-1.

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Data and Code Availability The data and the R script for analysis are available on GitHub at https://github.com/DominiqueMakowski/2020structure. The complete statistical report is available in Supplementary Materials 1 and a transcript of the complete survey is available in Supplementary Materials 2. The final scale with the administration and scoring instructions is available at Supplementary Materials 3. An interactive web application to compute the scores of the questionnaire is available at https://neuropsychology.shinyapps.io/proflier.

Author Contributions DM conceived the study. DM, TP and ZL participated in the study design, statistical analysis, data interpretation and manuscript drafting. AC coordinated the study. AC and AR provided input and expertise for the face validity of the items, provided input to the survey construction and performed a critical review of the manuscript. All authors read and approved the final manuscript.

Declarations

Ethics Statement The study was approved by the Institutional Review Board (Reference Number: IRB-2019-02-026) of Nanyang Technological University (NTU).

Conflict of Interest The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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